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The effect of physical contact on changes in fatigue markers following rugby union field-based training

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Abstract

Repeated physical contact in rugby union is thought to contribute to post-match fatigue, however, no evidence exists on the effect of contact activity during field-based training on fatigue responses. Therefore, the purpose of this study was to examine the effect of contact during training on fatigue markers in rugby union players.

Twenty academy rugby union players participated in the cross-over study. The magnitude of change in upper- and lower-body neuromuscular function (NMF), whole blood creatine kinase concentration [CK] and perception of wellbeing was assessed pre-training (baseline), immediately and 24 hr post-training following contact and non-contact field-based training. Training load was measured using mean heart rate, session rating of perceived exertion (sRPE) and microtechology (Catapult Optimeye S5).

The inclusion of contact during field-based training *almost certainly* increased mean heart rate (9.7; ±3.9%) and sRPE (42; ±29.2%) and resulted in *likely* and *very likely* greater decreases in upper-body NMF (-7.3; ±4.7% versus 2.7; ±5.9%) and perception of wellbeing (-8.0; ±4.8 % versus -3.4; ±2.2 %) 24 hr post-training respectively, and *almost certainly* greater elevations in [CK] (88.2; ±40.7% versus 3.7; ±8%). The exclusion of contact from field-based training *almost certainly* increased running intensity (19.8; ±5 %) and distance (27.5; ±5.3 %), resulting in *possibly* greater decreases in lower-body NMF (-5.6; ±5.2% versus -2.3; ±2.4%).

Practitioners should be aware of the different demands and fatigue responses of contact and non-contact field-based training and can use this information to appropriately schedule such training in the weekly microcycle.

Key Words: fatigue, recovery, team sport

Introduction

Rugby union match-play involves intermittent high-intensity activities including sprinting, rucking, mauling, scrummaging and tackling (Austin, Gabbett, & Jenkins, 2011; Quarrie, Hopkins, Anthony, & Gill, 2013) that are interspersed with periods of jogging, walking and standing (Cahill, Lamb, Worsfold, Headey, & Murray, 2013). The high intensity activities and collisions sustained during match-play result in acute post-match fatigue that may last for several days following competition. Common manifestations of fatigue include alterations in mood (West et al., 2014), perception of wellbeing (Roe, Till, et al., 2016) and hormone concentrations (Elloumi, Maso, Michaux, Robert, & Lac, 2003; West et al., 2014), reductions in neuromuscular function (NMF) (Roe, Till, et al., 2016; West et al., 2014), and elevations in markers of muscle damage (e.g. increase in creatine kinase concentration [CK]) (Cunniffe et al., 2010; Jones et al., 2014; Roe, Till, et al., 2016).

Understanding the fatigue response to match-play provides paramount information regarding the recovery of players and allows practitioners to appropriately plan the post-match microcycle (Roe, Till, et al., 2016). However, given that players spend a greater amount of time in field-based training than in competition (Bradley et al., 2015; Roe, Darrall-Jones, Till, & Jones, 2016), understanding the fatigue response to field-based training is also needed in order to optimise the training-recovery cycle in preparation for future competition (Fowles, 2006). Currently no study has investigated the fatigue responses of players to field-based training within rugby union players. Additionally, the inclusion or exclusion of collisions during field-based training may alter the demands of such training and influence the fatigue responses of players (Johnston, Gabbett, Seibold, & Jenkins, 2014). Therefore the presence or absence of collisions also needs consideration when assessing fatigue responses of rugby union players to field-based training alongside planning the training microcycle.

Previous research investigating the fatigue response of rugby league players following field-based small-sided games demonstrated *likely* greater decreases in ~~upper-body neuromuscular function (~~NMF~~)~~ at 24 hr post-training when training included collisions (Johnston et al., 2014). This was coupled with a *likely* greater increase in [CK], while changes in perception of wellbeing were *unclear*. In contrast, the exclusion of contact resulted in *likely* greater reductions in lower-body NMF as a result of greater running demands (Johnston et al., 2014). However, the findings from this study might not be applicable to rugby union training as each collision consisted of 5 seconds of shoulder pummels followed by 5 seconds of wrestling, which were unlikely to replicate the magnitude or frequency of collisions sustained during rugby union training (e.g. rucks and tackles). Furthermore, the 'off-side touch' style of small-sided games may have imposed different physical demands on players than experienced in rugby union training.

Therefore the aim of the present study was to examine the changes in markers of fatigue in response to contact and non-contact field-based training in rugby union players. This research would provide practitioners with important information regarding the fatigue response to field-based training inclusive or exclusive of contact, and thus allow appropriate scheduling of such training in the weekly microcycle.

Methods

Subjects

Twenty male players (age 17.6 ± 0.8 years; height 183.5 ± 7.4 cm; body mass 87.1 ± 11.9 kg) were recruited from a professional rugby union academy. Participants were excluded if they had an injury that prevented them from participating in the testing, or missed any testing session. Ethics approval was granted by the University ethics board and written informed assent was acquired from all subjects along with parental consent.

Design

A cross-over design was used to assess the magnitude of change in markers of upper- and lower-body NMF, whole-blood [CK] (an indirect measure of muscle damage) and perception of wellbeing following contact (CON) and non-contact (nCON) rugby union field-based training. The study was conducted during the fifth and sixth week of a pre-season period in order to ensure that players were adequately reconditioned following the off-season period to prevent an exaggerated fatigue response to training. Testing was undertaken pre- and immediately post-training, and 24 hr following the pre-training measures (Figure 1). Both training sessions were performed at the same time of day (1pm) under similar weather conditions exactly seven days apart. Participants were advised on nutritional intake but no recovery protocol was undertaken.

Training Intervention

The training sessions were designed to replicate a typical training session undertaken at the club. Each training session began with two 8-minute skill blocks (15 x 20 m pitch) during which players performed tackling (CON training) or passing (nCON training) drills. The players were then divided into teams of 5, with each team containing the same amount of forwards and backs (3 forwards and 2 backs) with the exception of one team, which consisted of 2 forwards and 3 backs. The teams each played three 3-minute small-sided games (5 versus 5; 15x20 m pitches) with 90 s of rest in between each game. Following this, players were then divided into 2 teams of 10, one consisting of 5 forwards and 5 forwards and the other of 6 forwards and 4 backs. The teams competed during three 3-minute (10 versus 10; 20x30m m pitch) with 90 s of rest between each game. The order of games and members of teams were kept the same for both CON and nCON training sessions.

The CON games consisted of full-contact tackles with up to two players from each team, inclusive of the tackler, contesting possession within the ruck area. Each team was allowed unlimited time to attack until one of the following occurred; a try was scored, a turn-over or penalty was conceded in the ruck area, or an error was made (i.e. forward pass or ball knocked forward). The nCON games consisted of non-collision tackles, which, in order to be deemed successful, involved the defending player touching the ball carrier with two hands. If a player was successfully tackled, both the attacking player and defender were required to lie down on the ground to simulate a tackle. Additionally, a secondary attacker and defender were required to position themselves beside the tackle area, simulating a ruck. Again, each team had unlimited possession until a try was scored, a turn-over or penalty was conceded in the ruck area, or an error was made. The games were refereed by experienced coaches in order to ensure that the rules were adhered to. No encouragement was given during the games, but technical coaching was provided during the rest periods.

INSERT FIGURE 1 HERE

Figure 1: Schematic of study design. Testing was inclusive of lower-body and upper-body neuromuscular function, whole blood creatine kinase concentration and perception of wellbeing.

Neuromuscular Function

Lower-body NMF was measured using mean power calculated from a countermovement jump (CMJ), while upper-body NMF was measured using flight-time calculated from a plyometric push-up. These measures have previously demonstrated good reliability in this population (typical error = 2.5 to 4.2%) (Roe et al., 2015). It has been recommended that a minimum sampling frequency of 200Hz be used for such measurement (Hori et al., 2009). Therefore the CMJ and plyometric push-up were performed on a portable force plate (400 Series Performance Plate, Fitness Technology, Adelaide, Australia) that was attached to a laptop with software (Ballistic Measurement System, Fitness Technology, Adelaide, Australia) that measured ground reaction forces at 600 Hz. A standardised 2-minute warm-up consisting of dynamic stretching was performed prior to the performance tests (walking lunges, squats, heel flicks, high knees, skipping, legs swings and 3 practice submaximal CMJ and Plyometric-push ups). Following the warm-up, players performed 2 maximal CMJ followed by 2 maximal plyomeric push-ups with 1-minute rest between each effort (Roe et al., 2015).

Creatine Kinase

Whole blood [CK] samples were collected from the non-dominant hand, middle fingertip of each subject. Approximately 30 µl of whole capillary blood was collected using a plastic capillary tube (MICROSAFE®, Safe-tec, Numbrecht, Ivyland, USA) and immediately analysed using reflectance photometry (Refletron® Plus, Boehringer Manheim, Germany). Prior to each session, the machine was calibrated using a standardised CK strip.. The reliability of this method has previously been reported (CV = 26.1%) (Roe et al., 2015).

Wellbeing

A 6-item questionnaire was adapted from McLean et al (2010) to rate each of sleep, fatigue, muscle soreness (upper- and lower-body), stress and mood on a 5-point Likert scale. Each item was rated from 1 to 5 in 1 score increments and overall wellbeing was assessed by summating all 6 scores. Reliability of this method has previously been reported (CV = 7.1%) (Roe et al., 2015). The questionnaire was administered prior to any other testing being undertaken (McLean et al., 2010). Participants completed the questionnaire on their own in order to prevent any influence from other players (Twist, Waldron, Highton, Burt, & Daniels, 2012).

Training Load

Subjective internal training load was quantified using the session rating of perceived exertion method (sRPE) (Foster et al., 2001) within 15-30 minutes of each session finishing, on a modified Borg scale. This rating was then multiplied by the time spent training to give a training load (sRPE-TL) in arbitrary units (AU) (Foster et al., 2001). Objective internal training load was assessed using mean heart rate. External training loads were assessed using GPS (10 Hz) and accelerometer (100 Hz) technology (Optimeye S5, Catapult Innovations, Melbourne, Australia). Metrics used were total distance and relative total distance (m/min) which have previously been proven valid and reliable (Johnston, Watsford, Kelly, Pine, & Spurrs, 2014), and Player Load™ slow, an accelerometer metric validated for quantifying the collision activity of rugby union players (Roe, Halkier, Beggs, Till, & Jones, 2016).

Statistical Analysis

All data were log transformed to reduce bias as a result of non-uniformity error. Data were all analysed for practical significance using magnitude-based inferences (Hopkins, Marshall, Batterham, & Hanin, 2009). For variables that were log transformed before modelling, the mean reported is the back-transformed mean of the log transformation, and the dispersion is a factor SD (×/÷) (Hopkins et al., 2009). The thresholds for a change to be considered practically important (the smallest worthwhile change; SWC) was set at 0.2 x between subject standard deviation (SD), based on Cohen's d effect size (ES) principle. The probability that the magnitude of change was greater than the SWC was rated as <0.5%, *almost certainly not*; 0.5-5%, *very unlikely*; 5-25%, *unlikely*; 25-75%, *possibly*; 75-95%, *likely*; 95-99.5%, *very likely*; >99.5%, *almost certainly* (Hopkins et al., 2009). Where the 90% Confidence Interval (CI) crossed both the upper and lower boundaries of the SWC (ES±0.2), the magnitude of change was described as *unclear* (Hopkins et al., 2009).

3. Results

Changes in lower-body NMF are presented in Figure 2. Following CON, CMJ mean power *very likely* decreased from 1215 ×/÷ 1.18 W to 1136 ×/÷ 1.15 W (-6.5; ±3.1 %) immediately post-training, but demonstrated *likely* trivial changes at 24 hrs (1187 ×/÷ 1.17, -

2.3; ±2.4%) (A). In response to nCON, CMJ mean power *likely* decreased from 1229 ×/÷ 1.15 W to 1161 ×/÷ 1.18 W (-5.5; ±3.3%) and 1162.6 ×/÷ 1.17 W (-5.4; ±5.2%) immediately and 24 hr post-training respectively (A)~~)~~. Decreases in CMJ mean power were *unclear* between CON and nCON immediately post-training, while *possibly* greater in nCON than CON 24 hr post-training. Changes in CMJ mean force (D) were *almost certainly* trivial for both CON and nCON at all time-points.

INSERT FIGURE 2 HERE

Changes in upper-body NMF function are presented in figure 3. In response to CON, plyometric push-up flight time *likely* decreased from 0.394 ×/÷ 1.19 to 0.372 ×/÷ 1.18 s (-6.4; ±3.9%) and 0.365 ×/÷ 1.22 s (-7.3; ±4.7%) immediately and 24 hr post-training respectively (A). Following nCON, plyometric push-up demonstrated a *likely* trivial change from 0.399 ×/÷ 1.18 s to 0.410 ×/÷ 1.20 s (1.6; ±2.5%) but a *possible* increase at 24 hr post-match (0.412 ×/÷ 1.15 s, 2.7; ±5.9%) (A). Decreases in plyomteric push-up flight time (C) were *very likely* greater in CON than nCON immediately post-training, while *likely* greater in CON than nCON 24 hr post-training. Decreases in mean force (D) were *likely* to *almost certainly* trivial for both CON and nCON at all time-points.

INSERT FIGURE 3 HERE

Changes in [CK] and perception of wellbeing are presented in Figure 3. Following CON, [CK] *almost certainly* increased from 414 ×/÷ 1.76 IU/L to 691 ×/÷ 1.47 IU/L (66.9; ±22.5%) immediately post training and continued to rise to 779 ×/÷ 1.56 IU/L (88.2; ±40.7%) 24 hr post-training (A). Following nCON, [CK] *almost certainly* increased from 395 ×/÷ 1.80 IU/L to 543 ×/÷ 1.61 IU/L, but returned to near pre-training concentration~~levels~~ (410 ×/÷ 1.59 IU/L) at 24 hrs post-training (A). Increases in [CK] were *likely* greater in CON than nCON ~~(~~immediately post-training, while *almost certainly* greater in CON than nCON ~~-~~24 hr post-training (A). Perception of well-being was *almost certainly* reduced from 19.8 ×/÷ 1.15 to 18.2 ×/÷ 1.15 (-8.0; ±4.8%) 24 hr after CON (D), while *likely* reduced from 21.5 ×/÷ 1.12 to 20.8 ×/÷ 1.13 (-3.4; ±2.2%) following nCON (D). Decreases in perception of wellbeing were *likely* greater in CON than nCON at 24 hr post-training. When questionnaire items were analysed individually, there was an *almost certain* and *likely* greater change in perception of upper-body and lower-body soreness following CON, while the differences between changes in other items were *unclear*.

INSERT FIGURE 4 HERE

Total distance was *almost certainly* greater (27.5; ±5.3 %) during nCON (2543 ×/÷ 1.09 m) than CON (1968 ×/÷ 1.14 m). Relative distance was *almost certainly* greater (19.8; ±5.0 %) during nCON (79.4 ×/÷ 1.09 m.mim^{-1}) and CON (65.1 ×/÷ 1.18 m.min^{-1}). Player Load^{TM} slow was *almost certainly* greater (56.5; ±5.7 %) during CON (165 ×/÷ 1.17 AU) than nCON (108 ×/÷ 1.13 AU). Mean heart rate was *almost certainly* greater (9.7; ±3.9 %) during CON (166 ×/÷ 1.07 bpm) than nCON (152 ×/÷ 1.08 bpm) while sRPE was also *almost certainly* greater (42; ±29.2%) following CON (417 ×/÷ 1.56) than nCON (294 ×/÷ 1.35).

4. Discussion

This study examined the fatigue responses to contact and non-contact field-based training in rugby union players. The inclusion of contact during field-based training increased subjective and objective internal training load and resulted in greater upper-body neuromuscular and perceptual fatigue and greater elevations in [CK]. The exclusion of contact from field-based training increased running intensity and distance, resulting in greater lower-body neuromuscular fatigue.

Upper-body neuromuscular function demonstrated *likely* greater reductions following CON than nCON at 24 hr post-training, indicating neuromuscular fatigue. This reduction may be attributed to the substantial involvement of the upper-body during rugby union collisions (Hendricks, Matthews, Roode, & Lambert, 2014), and the resultant trauma to local tissues (Johnston, Gabbett, Jenkins, & Hulin, 2015). Similar results were reported by Johnston and colleagues (2014), who observed a *very likely* greater decrease in plyometric push-up peak power 24 hr following contact small-sided games in rugby league players. The greater probability of decrease above the SWC may be due to the particular metric used to measure upper-body NMF. It has been shown that power variables demonstrate larger changes than flight-time in response to training for the CMJ (Roe et al., 2016). Unfortunately, unlike in the study by Johnston and colleagues, in the present study flight-time was used instead of peak power to measure upper-body NMF due to the unacceptable reliability of peak power in this population (Roe et al., 2015). Collectively, however, these findings suggest that upper-body NMF is deceased 24 h following contact training. It may therefore be prudent to plan upper-body resistance training earlier in the weekly microcycle, or allow adequate recovery time following field training inclusive of contact. Furthermore, as plyometric push-up peak power is associated with tackling ability (Speranza, Gabbett, Johnston, & Sheppard, 2015), recovery of upper-body neuromuscular function may be important to prevent reduced tackle performance in subsequent collision training or match-play.

This study found *almost certainly* greater increases in [CK] following CON than nCON 24 h post-training. This finding supports previous research in rugby union that demonstrated an almost perfect relationship between collisions and increases in [CK] 24 h post-match (Takarada, 2003), and suggests that collisions are a major contributor to skeletal muscle damage in rugby union players. The rise in [CK] was greater than that observed in the previously mentioned study by Johnston et al (2014). The authors found a *likely* increase in [CK] that rose 54±32% above pre-training measures at 24 hr post-training, which is lower than in the present study (88.2; ±40.7%). The difference is possibly due to the nature of contact. The collisions in Johnston and colleagues' study consisted of 5 seconds of shoulders pummels followed by 5 seconds of wrestling, which were likely to be of lesser magnitude than the tackles and rucks contested in the present study. Indeed, the accumulation of Player Load slow, an accelerometer metric that has shown strong relationships with collisions in rugby union players (Roe, Halkier, et al., 2016) was nearly as high during CON in the present study as during a competitive rugby union match (167±28 versus 197±47 AU) (Roe, Till, et al., 2016). These results suggest that as the intensity and volume of contact in training increases, so too do markers of muscle damage.

It must be pointed out that the pre-training concentrations~~levels~~ of [CK] (414 ×/÷ 1.74 IU/L) in the present study were high relative to in-season concentration~~level~~s (212 ×/÷ 1.96 IU/L) formerly reported in this cohort (Roe, Till, et al., 2016). It has previously been demonstrated that [CK] concentration~~levels~~ increases during times of high training stress, but may return to baseline concentration~~levels~~ as individuals adapt to the training stimulus (Alaphilippe et al., 2012; Hoffman, Kang, Ratamess, & Faigenbaum, 2005) via the "repeated bout effect" (Koch, Pereira, & Machado, 2014). It is therefore possible that although the present study was undertaken during the middle of pre-season, the four weeks of training preceding data collection were not long enough for such adaptation to occur, resulting in the high pre-training concentration ~~level~~s observed. To this end, the magnitude of increase in

[CK] reported may be understated. Therefore future research is required in a more controlled setting in order to determine the [CK] response of rugby union players to field-based training.

Although post-training elevations in [CK] may be primarily attributed to tissue damage as a result of blunt trauma during collisions in rugby union, other non-contact mechanisms may have also played a part. From Figure 2 it can be seen that there was an *almost certain* acute elevation in [CK] immediately post-training following nCON. This acute increase in [CK] may be attributed to eccentric muscle damage as a result of high-speed locomotion (Jones et al., 2014; Wiewelhove et al., 2015). Nevertheless, this increase was *likely* trivial at 24 h post-training, suggesting full recovery.

There was a *likely* greater decrease in perception of wellbeing following CON than nCON. In addition, sRPE was *almost certainly* greater following CON than nCON . This is in contrast to findings from the aforementioned study by Johnston et al (2014), where differences between CON and nCON were *unclear* for both measures. As previously discussed, the frequency and magnitude of contact in the present study was likely to be greater during CON, as demonstrated by the large accumulation of Player Load™ slow, thus resulting in a larger perception of effort during, and the greater reductions in wellbeing 24 hr following CON. Indeed, the accumulation of accelerometer load during training has been shown to have large to very large relationships with sRPE in rugby league players (Lovell, Sirotic, Impellizzeri, & Coutts, 2013). Furthermore, perception of upper- and lower-body muscle soreness were *almost certain* and *likely* greater following CON than nCON respectively, which would have contributed to the greater reduction in perception of wellbeing.

In addition to sRPE, CON also resulted in *almost certainly* greater heart rate than during nCON. Similarly, previous research by Johnston and colleagues (2011) demonstrated greater mean heart rate and sRPE when tackles were added to a repeated sprint training session. These finings demonstrate the greater physiological and subjective load of collision-based training, which is reflected in the negative changes in the majority of post-training measures of fatigue in the present study.

In contrast to upper-body NMF, a *possibly* greater reduction in lower-body NMF was observed following nCON than CON 24 hr post-training. This may be the result of the *almost certainly* greater locomotive demands of nCON, and the eccentric damage associated with high-speed running (Jones et al., 2014; Wiewelhove et al., 2015). In comparison, Johnston et al (2014) reported *likely* greater reductions in lower-body NMF following non-contact versus contact small-sided games in rugby league players. The greater probability of reduction above the SWC may be explained by the difference in demands of the particular games played. Johnston et al. (Johnston et al., 2014) implemented 'off-side touch' which resulted in a very high running intensity (140 m/min), which are not representative of a match (95.8±18.6 m/min (Twist et al., 2014)). In contrast, the games in the present study resulted in a greater distance covered (2552m versus 2240m), but at a much lower running intensity (79.9 m/min), although this is more representative of match-play (74±6 m/min (Roe, Till, et al., 2016)). Collectively however, these findings demonstrate that the exclusion of contact from field-based training increases the locomotive demands of field-based training and results in greater decreases in lower-body NMF 24 hr post-training. Such information can be used by practitioners when scheduling activities that require high levels of lower-body power (e.g. power or sprint training) during the weekly microcycle.

The results of the present study also demonstrate the individual nature of fatigue response to field-based training in rugby union players, similar to those found following match-play (Roe, Till, et al., 2016) From Figures 1 to 3 (B, C, E and F) it can be seen that players often differed from the group mean response, some presenting with greater changes in fatigue markers, while others not experiencing any fatigue at all. These findings emphasise that although understanding a group response provides valuable information on fatigue induced by field-based training inclusive or exclusive of contact, it is important for practitioners to monitor fatigue response of each individual player following training. Furthermore, future research is needed to understand the mechanisms that contribute to such individual responses.

A limitation of the present study is the lack of follow up past 24 hr. However, data collection at 48 hr post-training was not possible due to the players' training schedule. In addition, although players were instructed not to engage in any contact during nCON, accidental collisions with other players did occur. A further limitation of the present study is that participants were not randomised, and a control group was not included. However, due to this research being conducted in an applied setting where players were required to adhere to a strict training schedule, such methods could not be employed. Finally, although the training sessions were designed to replicate a typical field-based training session at the rugby club, these sessions may not be representative of training at other clubs. Therefore caution should be advised when applying the findings from this study to different training situations.

Conclusions

The inclusion of contact during field-based training increases subjective and objective measures of internal training load and results in greater upper-body neuromuscular and perceptual fatigue, and greater elevations in [CK]. The exclusion of contact from field-based training increases running intensity and distance, resulting in greater lower-body neuromuscular fatigue. Practitioners should be aware of the different fatigue responses of contact and noncontact field-based training and can use this information to appropriately schedule such training in the weekly microcycle. Furthermore, the results demonstrate the individual responses of players to contact and non-contact field-based training, highlighting the need for the individual monitoring of players.

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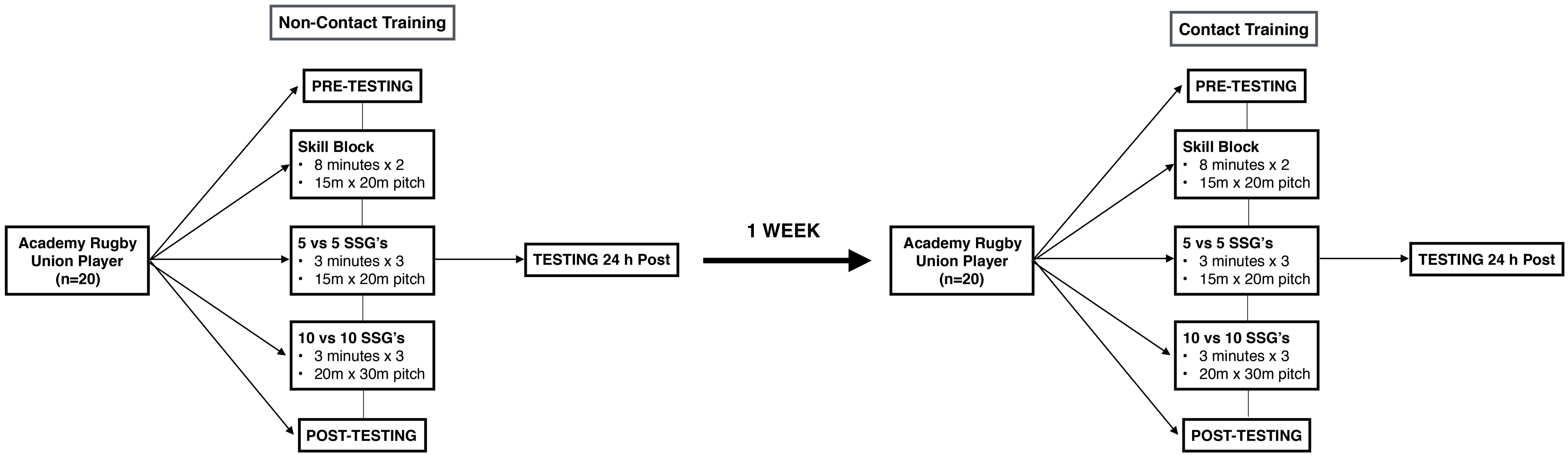
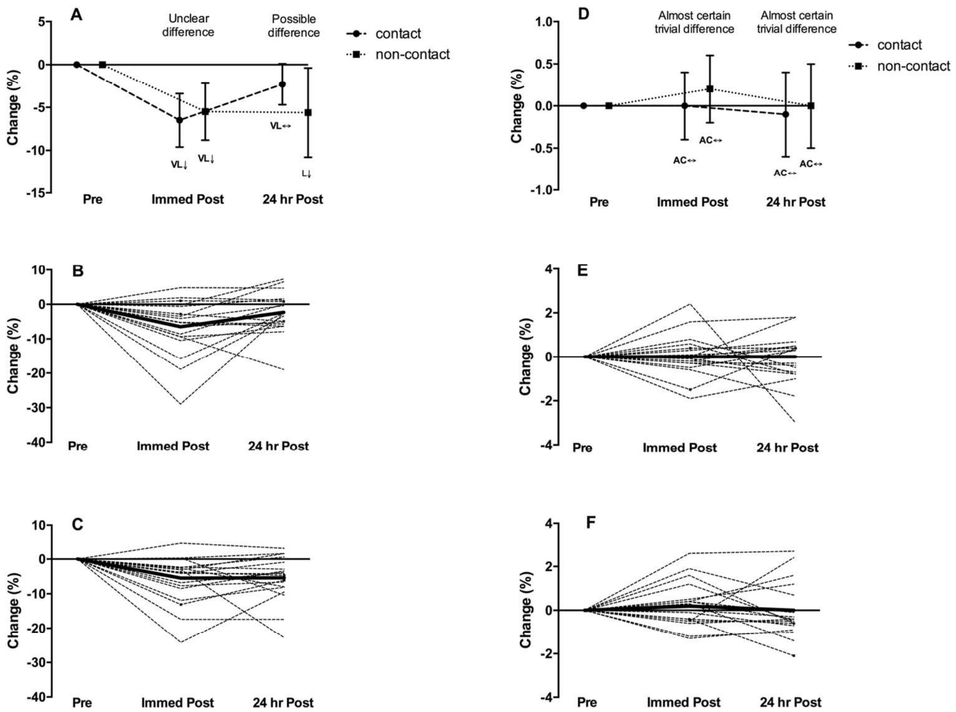
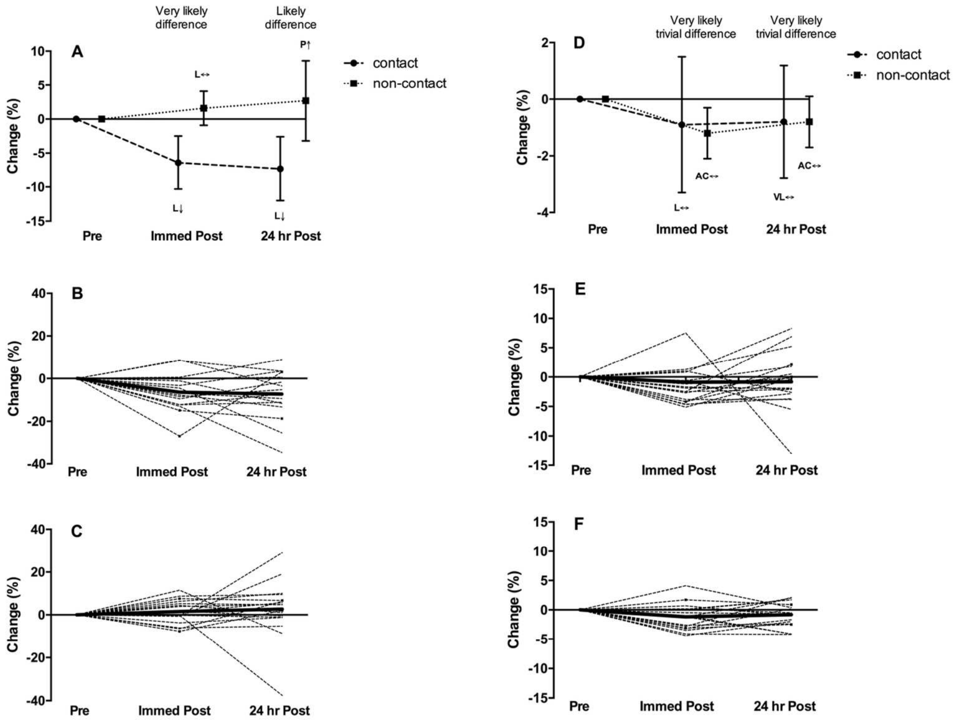

Non-Contact Training
Academy Rugby Union Player (n=20)
PRE-TESTING
Skill Block
• 8 minutes x 2
• 15m x 20m pitch
5 vs 5 SSG's
• 3 minutes x 3
• 15m x 20m pitch
10 vs 10 SSG's
• 3 minutes x 3
• 20m x 30m pitch
POST-TESTING
TESTING 24 h Post
1 WEEK
Contact Training
Academy Rugby Union Player (n=20)
PRE-TESTING
Skill Block
• 8 minutes x 2
• 15m x 20m pitch
5 vs 5 SSG's
• 3 minutes x 3
• 15m x 20m pitch
10 vs 10 SSG's
• 3 minutes x 3
• 20m x 30m pitch
POST-TESTING
TESTING 24 h Post



Graphs are mean changes in CMJ mean power (A) and mean force (D). Change data are percentage change with 90% confidence interval bars. Above graph ratings of probability refer to between-group comparisons. Below graph ratings of probability refer to within-group changes; P = possibly, L = likely, VL = very likely, A = almost certainly, ↑ = increase, ↓ = decrease, ↔ = trivial. Individual changes are shown for CMJ mean power following contact (B) and non-contact (C) training, and mean force following contact (E) and non-contact training (F).

133x100mm (300 x 300 DPI)



Graphs are mean changes in plyometric push-up flight time (A) and mean force (D). Change data are percentage change with 90% confidence interval bars. Above graph ratings of probability refer to between-group comparisons. Below graph ratings of probability refer to within-group changes; P = possibly, L = likely, VL = very likely, A = almost certainly, ↑ = increase, ↓ = decrease, ↔ = trivial. Individual changes are shown for plyometric push-up flight time following contact (B) and non-contact (C) training, and mean force following contact (E) and non-contact training (F).

128x98mm (300 x 300 DPI)

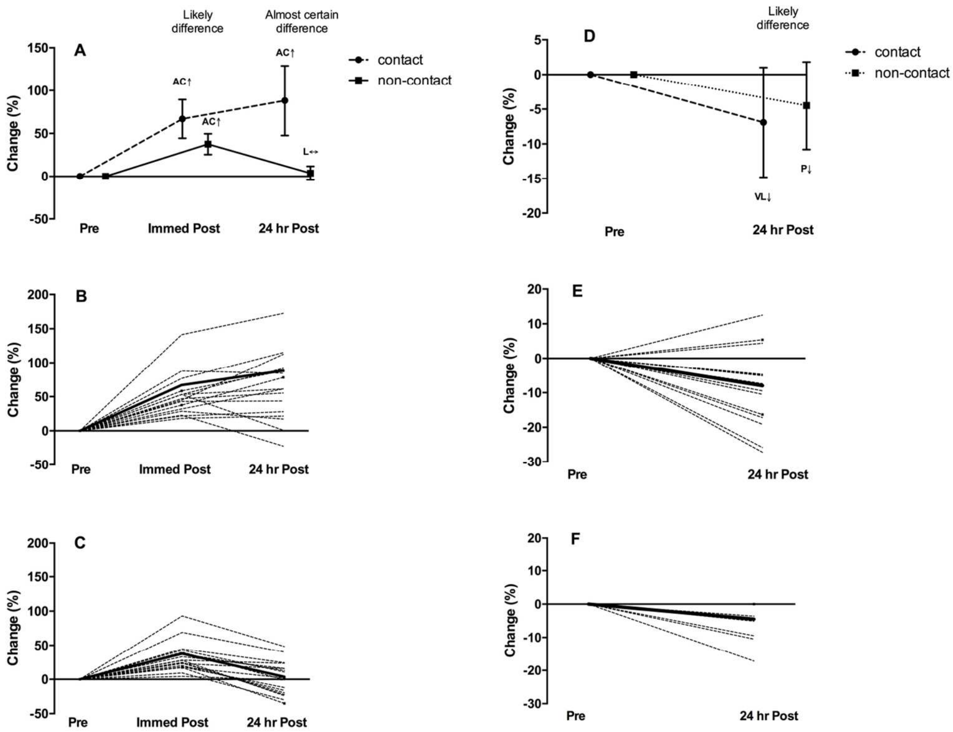


Figure 4: Graphs are mean changes in creatine kinase (A) and wellbeing (D). Change data are percentage change with 90% confidence interval bars. Above graph ratings of probability refer to between-group comparisons. Below graph ratings of probability refer to within-group changes; P = possibly, L = likely, VL = very likely, A = almost certainly, ↑ = increase, ↓ = decrease, ↔ = trivial. Individual changes are shown for creatine kinase following contact (B) and non-contact (C) training, and wellbeing following contact (E) and non-contact training (F).

130x100mm (300 x 300 DPI)